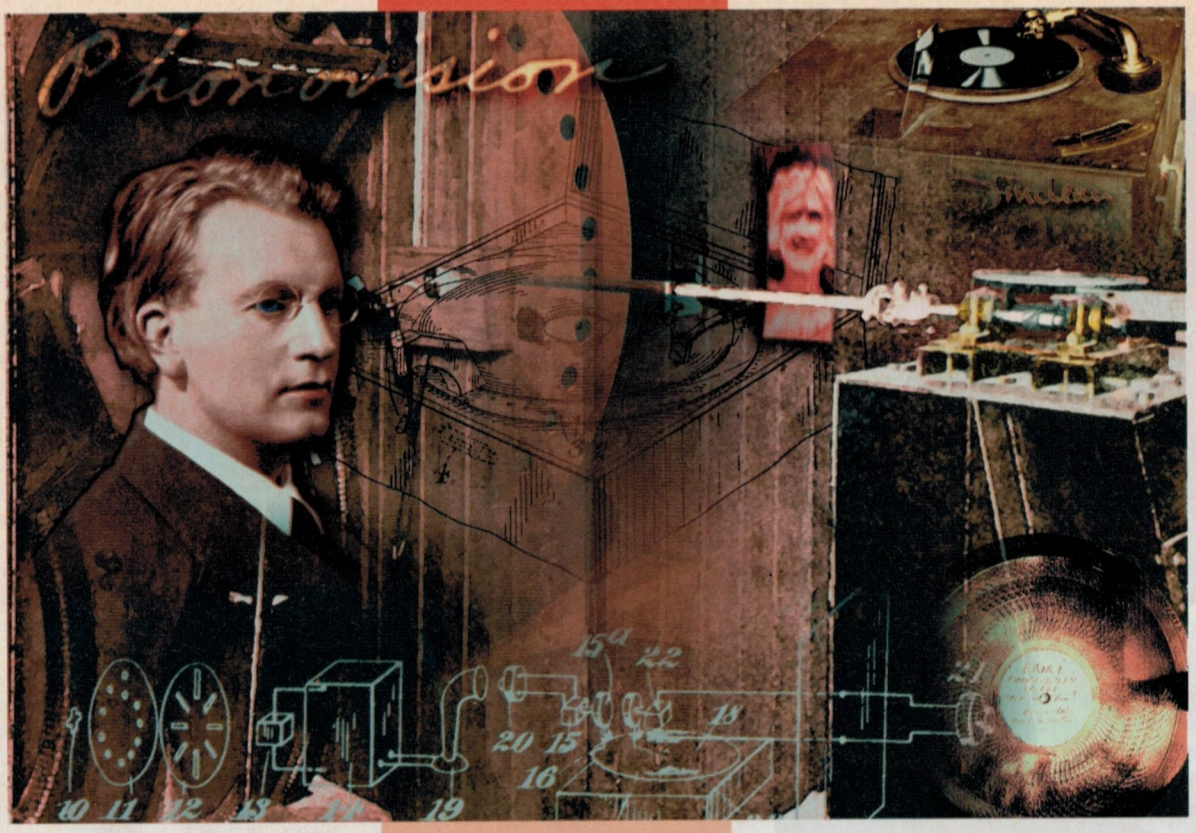


Restoring Baird's image

For the first time, Don McLean reveals detailed new information from the world's earliest recordings of television.

John Logie Baird recorded television images in his laboratory in London soon after giving the world's first demonstration of television. This was well before television broadcasting began.[1]

Baird made the recordings with a view to developing a mass-market videodisc player. But he did not succeed, primarily due to distortion during recording.

Studying the signal and its faults yields the first detailed information on Baird's equipment and the problems that he encountered. Correcting the faults gives us the first television images from the dawn of television.

The first video disc

Baird's television 'standard' of the late twenties comprised only 30 lines per picture shown at 12.5 pictures per second. The bandwidth was narrow enough for the signal to be handled like audio.

Baird used this to attempt a means of capturing television images onto audio wax cylinders and discs, **Fig. 1**. He called this process 'Phonovision'.

His 1926 patent[2] described the basic idea of simultaneously recording vision and sound signals. In 1928, he filed for a patent[3] on the 'Phonovisor'. Had it been successful, the Phonovisor would have been the world's first consumer videodisc in a combined playback *and* display system. Its extreme simplicity of construction would also have made it low cost.

We know from the work described here that the duration of a disc with vision and sound could have been only a minute or so. This would have been sufficient for a music video similar – in marketing terms at least – to the *TelDec* system of the seventies and cd video singles of the eighties.

Baird's videodisc system never became a product[4] despite the experiments being heavily promoted. Bizarrely, Baird did demonstrate the *sound* of the vision signal. He declared[5] that he could recognise something about the subject from listening to the vision signal. Very likely, he only did this to suggest that he was making progress.

First sightings

In June 1928, Baird reported that he had managed to see a "crude smudgy" rendition on playback but that it was "more of a curiosity".[6] By 1931,

Donald F McLean B.Sc(Hons) CEng FIEE

Fig. 1. The Phonovision discs all resemble 25cm (10in) diameter single-sided 78rev/min 'shellac' audio discs. A distinguishing feature is the radial structure caused by Baird's synchronous recording method.

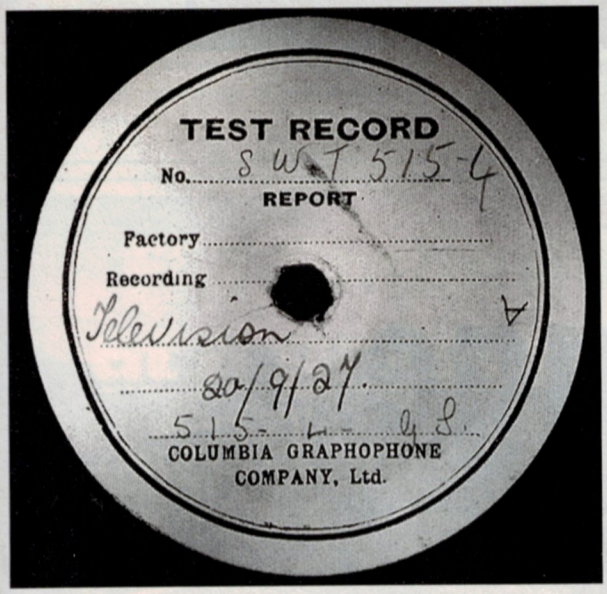


Fig. 2. Most Phonovision discs have a dated 'Columbia Graphophone Company TEST RECORD' label. This one is from the earliest known recording of television, featuring a rather wooden performance by 'Stookie Bill'.

Fig. 3. Instead of live performers, Baird often used a ventriloquist's dummy head in his experiments as a test subject. He had several such heads – all called 'Stookie Bill'. The photograph on the left is a different model from that restored from the 1927 recording on the right. The vertical line shearing is caused by errors in constructing the scanning disc, cf *Fig. 4.*

reports were still describing Phonovision as a "scientific curiosity".[7] From then on, Phonovision dropped out of the news.

In all that time, Baird never demonstrated *pictures* from the discs, most likely due to their poor quality.

This is supported by the various attempts over the years since then to view pictures from the discs. Analogue filtering and oscilloscope displays showed that the recorded quality was too poor to give any recognisable imagery. But by using a computer to capture, store, analyse and process the raw signal, I have managed to restore the recordings.

The recorded quality of Phonovision is so poor that Baird could not have seen the images at the quality presented here. These experimental images fall far short of studio quality. They should not be considered as typical of Baird's and the BBC's subsequent 30-line broadcasts.

Never intended for public appraisal, the discs are merely a snapshot view of his experimental period on a subject he himself deemed unsuccessful.

The re-discovery of Phonovision

Attention on Baird's other achievements and the great strides in electronic television technology passed Phonovision by. For decades, the discs were spread around the country, until the work described here brought them together and subsequently their historic value was recognised.

After many years of searching, there are today only five different vision-only recordings from Baird's experiments. They are listed in the panel.

Some of the discs have a Columbia Graphophone Company Test Record label, **Fig. 2**, indicating Columbia had been engaged in cutting and pressing the discs. Each disc has a reference number for the session and take, consistent with Columbia Graphophone Company practice, **Table 1**.

The house of Ben Clapp, Baird's first engineer, was bombed in the Second World War destroying all but one of his collection of Phonovision discs.[8] The surviving disc, SWT515-4, is the earliest-known recording of television in the world made in September 1927 – a mere twenty months after Baird's

Table 1. Details of all known Baird Phonovision discs.

Reference No.	Date	Content discovered after restoration
SWT515-4	20 Sep 1927	operator's hand and 'Stookie Bill'
RWT620-4	10 Jan 1928	over-modulated recording of 'Wally' Fowlkes' head
RWT620-6	10 Jan 1928	'Wally' Fowlkes' head in motion (marred by amplifier oscillation)
RWT620-11	10 Jan 1928	'Wally' Fowlkes' head in motion
RWT115-3	28 Mar 1928	Baird's temp, Miss Mabel Pounsford – head and shoulders

historical first demonstration.

This disc contains a test signal – a simple white bar or edge – and one of Baird's dummy heads **Fig. 3**. It is a doubly-historic disc: it was also one of a few that Baird used to transmit test signals from Ben Clapp's house in Coulsdon to New York in late 1927[9] for the Transatlantic Television experiments. Given both the distortions on the disc and its slow frame rate, it was probably used only as a readily identifiable sound to test reception.

The 'Wally' recordings of January 1928 are the earliest of a living face. The name 'Wally' is scratched on the disc surface and the image has a close resemblance to Wally Fowlkes – one of Baird's laboratory assistants.[10]

On the discs, the subject turns his head from profile to full face and looks up and down, **Fig. 4**. When he moves his head towards and away from the camera, the effect is as if there is a vertical sheet of light immediately in front of the camera.

A picture of a Phonovision disc in a July 1928 magazine is in fact the same disc as RWT115-3 dated 28 March 1928, **Fig. 5**, supporting the validity of the dates written on the disc labels. No one knew who "Miss Pounsford" was until an appeal on Channel 4 in 1993 over the restored pictures brought success.

This was now Mabel Pounsford, a temporary secretary to Baird in the twenties, **Fig. 6**.

Signal capture. The first step in restoration is to capture the raw video signal into the computer. Recorded directly onto the disc without modulation, the video signal is played back from a conventional record deck and sampled into the computer using ideally a clock extracted from the turntable rotation.

Analogue pre-processing corrects for the disc cutter's frequency characteristic (Blumlein[11]) and phase response. The digitised signal is stored in a disc file for analysis and correction.

Processing the signal. Analysing the video signal reveals features common to all five Phonovision discs. Every disc has exactly three 30-line tv frames, i.e. 90 lines, per revolution without either separate or combined[12] audio soundtrack.

There are no embedded synchronisation pulses. The 30-line system did not support them, relying on video content for line synchronisation and manual adjustment for frame sync. The principal idea behind Phonovision was not to rely on synchronisation from the video signal but to link the camera physically with the record platter to give an exact number of frames on each revolution of the disc. Baird obviously understood the problems caused by playback variation.

Timebase distortion. This mechanical linkage gave rise to the most serious problem plaguing the Phonovision discs – fluctuation in speed. Ironically, Baird was developing Phonovision to get round that very problem. Whereas live broadcasts would give as steady a picture as the camera generating it, a recording would be subject to minor random speed changes that would ruin a sync-less television picture.

There are three separate types of timebase distortion.

Offsets in the start of certain lines, but constant from frame to frame, Figs 3 and 4. This distortion caused by errors in positioning the lenses on the Nipkow scanning disc. A slight circumferential error – radial errors do not show up – would give rise to an early or late start to a line.

The maximum error is 3% of line

Fig. 4. From the January 1928 session, this is Wally Fowlkes, one of Baird's assistants and commonly televised as a test subject. The name 'Wally' was scratched on the disc surface.

Fig. 6. Mabel Pounsford is pictured on the left many years after her short spell as a temp to Baird. The label on the disc incorrectly says "Woman smoking a cigarette". The 'cigarette' is, in fact, her chin suffering massive timebase distortion. Restoration converts her to a non-smoker (right).

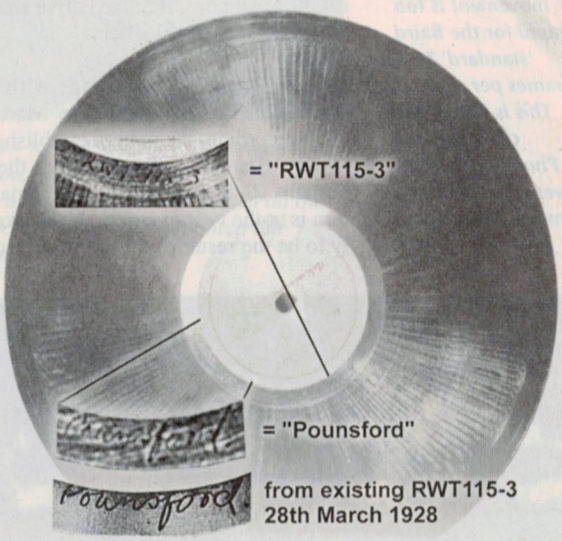


Fig. 5. Proof of the discs' ages comes from a photograph from July 1928 from which the signature "Miss Pounsford" and the serial number "RWT115-3" can be read. The current Phonovision disc dated 28 March 1928, bottom left, has identical markings.

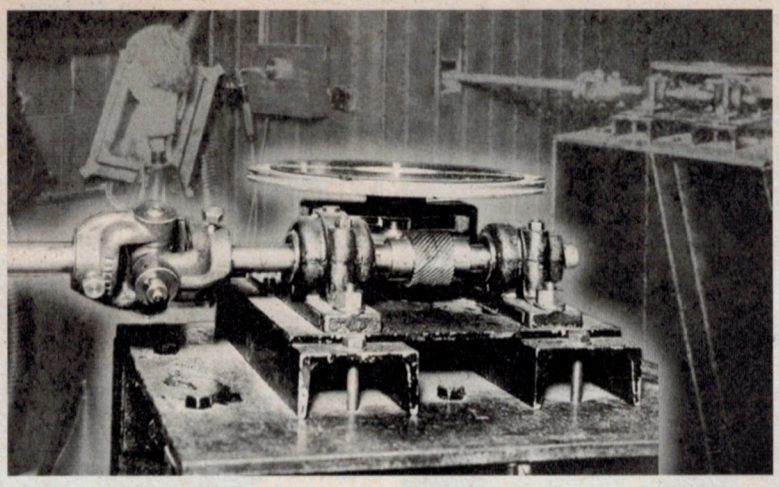


Fig. 7. This composite photograph shows the main Phonovision transport with helical gear assembly and universal joint coupling. A major component of the timebase distortion can be attributed to such a coupling.

length for line 11, indicating a 0.4° error in its position. For a 150cm-diameter Nipkow disc, this amounts to a 4mm offset error in drilling the hole for the 6cm wide lens. Notably this pattern of offsets is common to the September 1927 and January 1928 recordings indicating the same scanning disc was used for both sessions.

Low frequency variation in timebase at frequencies up to the frame rate. The effect is worse in the September 1927 recording, improves by January 1928 and is absent from the March 1928 recording. This indicates where Baird was focusing his effort.

The slow variation suggests a flexible coupling, most likely at the motor driving the Nipkow disc. A spectral analysis of the timebase errors shows an unusually high content at the second harmonic of the tv frame rate 180° phase-shifted to the fundamental.

An off-axis universal joint coupling such as in **Fig. 7** would give such a result. A bent or misaligned drive shaft would give the same effect.

High frequency variation within frame. Present only on the March 1928 recording, the pattern establishes in the first few seconds and then remains static throughout. As the pattern is at the tv frame rate, this is likely to be the result of mechanical resonance in the coupling between the Nipkow disc and the gearing assembly.

The lack of low-frequency variation apparent in the earlier discs indicates Baird had moved to a hard mechanical linkage between Nipkow disc and recording deck. This is undoubtedly the reason for this resonance.

Restoring the timebase

The absence of any synchronising information in the video signal means that correction has to rely on video content. With no low frequencies and limited video bandwidth, the Phonovision signal resembles a modulated sine wave. This makes the restoration of the timebase a complex process.

Over the years I have developed a hybrid solution based on several multi-pass algorithms using variants on auto-correlation.[13] The parameters for the algorithms are tuned to the Phonovision session on which the disc was made.

Recording speed. To make these recordings, Baird dropped his tv frame rate from 12.5 per second to around 4 per second to give about 80rev/min at the disc cutting equipment. The Columbia engineers probably dictated this rate.

Three clues support this. The first is a sequence of 11 frames in which the subject turns from face-on to the right and then to the left, **Fig. 8**. This speed is unnatural at Baird's standard of 12.5 frames per second.

The second clue is the absence of low frequencies. Recording at 80rev/min would give a line frequency of only 120Hz with may contribute to this effect.

The third clue is that the quality of the recording groove is excellent, suggesting a recording speed of 78 to 80rev/min.[14]

In his laboratory, Baird would have had extreme difficulties seeing any picture at this low frame rate, as his display had no persistence.

Signal problems

The discs all suffer from lack of video bandwidth. Given that these discs were professionally recorded, this is a real surprise.

Fortunately on the earliest recording there is a bright bar or edge whose impulse response allows us to make an estimate of the system's bandwidth. The signal is reasonably flat within 1dB only between 250Hz and 1200Hz at 78rev/min.

It may be that, as shown on his 1926 patent, Baird used a microphone in front of a loudspeaker rather than a direct connection. The Columbia engineers may well have insisted on some such arrangement. That the disc-cutter has managed to record the mechanical rumble from the Nipkow disc but not the low video frequencies shows that the low frequencies were lost *before* recording.

Image processing. The unusual nature of the video amplitude distortion required me to develop a custom suite of image processing tools. Digital filtering tackled the frequency and phase errors while a time-domain image tracking algorithm reduced image noise.

Drop-outs and clicks were removed by a new algorithm based on statistical comparison of adjacent lines and frames. The restored images were re-sampled onto an arc-scan grid to sim-

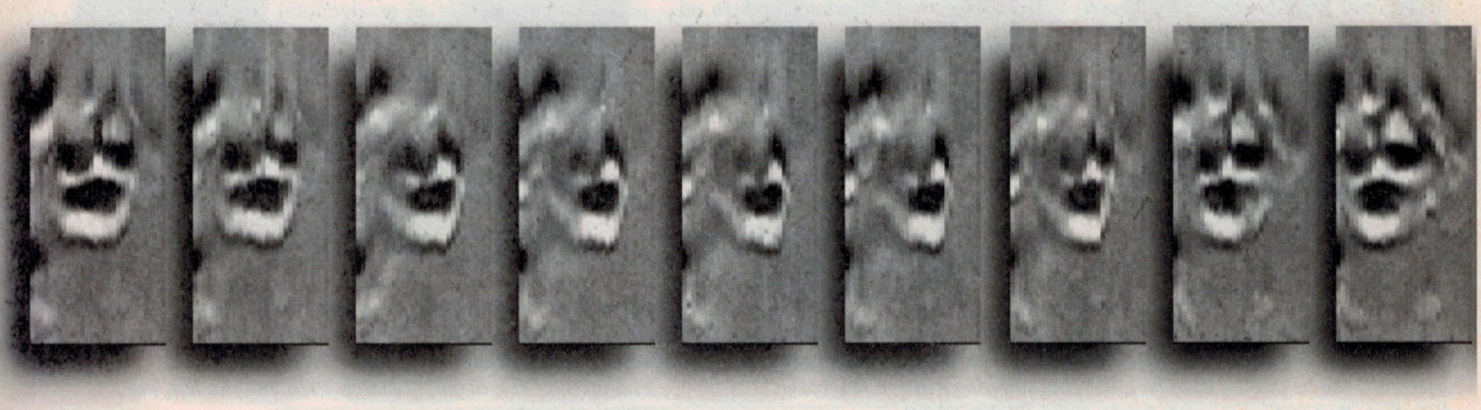


Fig. 8. A series of consecutive 30-line frames showing Miss Pounsford turning her head from side-to side. The movement is too rapid for the Baird 'standard' 12.5 frames per second. This is one of the clues that the Phonovision discs were recorded at a much lower frame rate.

ulate the contemporary display method.

Ideally the images shown here should be tinted the orangey-red of neon – the variable light source used for display.

Sound and vision. At the start of each of the three discs recorded in January 1928, a rumbling sound drops logarithmically in pitch over several seconds. The profile of the drop is identical for a high-pitched shriek associated with the video content, **Fig. 9**. Notably though, the video signal maintains constant pitch throughout this period. This is a great piece of evidence telling us several things.

The shriek dropping in pitch is a sound external to the platter: the platter is coming up to speed and hence the sound appears to fall in pitch. That the video stays at constant pitch tells us that, for the January 1928 session, the Nipkow disc and record platter are mechanically linked.

A rumble at TV frame rate also drops in pitch. This is the sound of the Nipkow disc turning. The shriek is most likely Baird's video amplifier bursting into oscillation.

Analysing the graph tells us that the disc-cutter was started when the Nipkow disc had reached 20% of final speed after just over two rotations. In the following six rotations, it had achieved 50% speed and after a further 24 rotations had reached 90% of maximum speed of around four rotations per second.

Knowing the mass of the Nipkow disc, we could estimate the torque force of Baird's main drive motor.

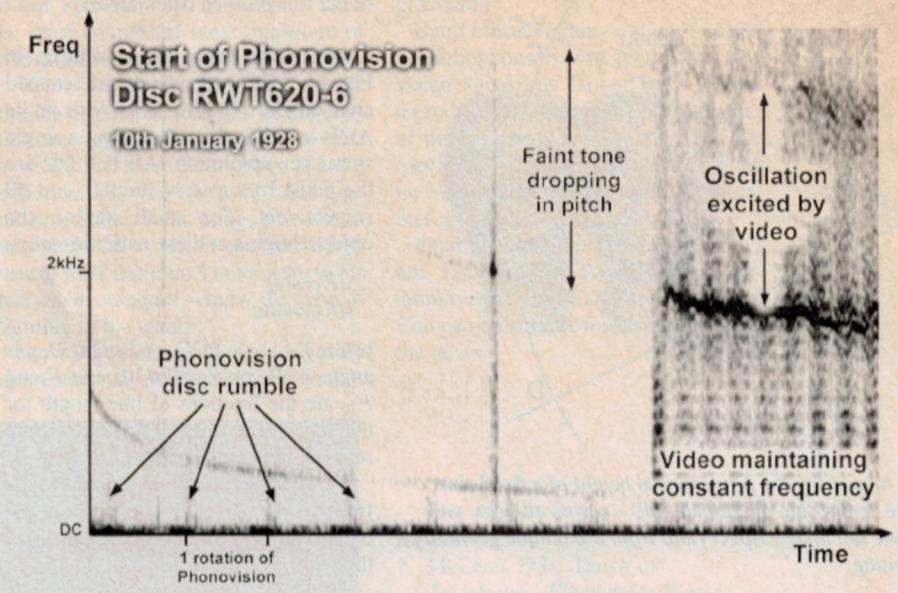


Fig. 9. A sonogram of the start of a January 1928 recording provides evidence that the scanning disc and Phonovision turntable were mechanically linked. In addition, Baird's video amplifier in oscillation – evident from the central black line – gives us the acceleration profile of his camera disc.

How Baird recorded Phonovision

A few pictures exist from publications of 1928 of Baird's Phonovision recording studio. By extracting common features in each of the pictures, I have built a computer 3D model for the laboratory.

The Phonovision disc on the turntable gives the absolute reference for dimensions. The lessons learned from the discs support the model and suggest that the studio portrayed could well have been used to make or even replay the Phonovision discs.

Underneath the record platter is a helical-gear assembly that transfers the rotation of the drive-shaft to the turntable, **Figs** 7, **10, 12**. Measuring the relative diameters of the gear parts from the photographs gives a ratio of 3:1. For every three turns of the drive shaft, there is one revolution of the record platter. This matches what we see with the Phonovision discs.

These discs all have 90 lines per revolution, so each revolution is exactly three frames. If the shaft were directly coupled to the scanning disc, then you would expect exactly three frames per revolution. Following the direction of rotation of the record platter through the gears, Fig. 12, the shaft entering the wall rotates clockwise.

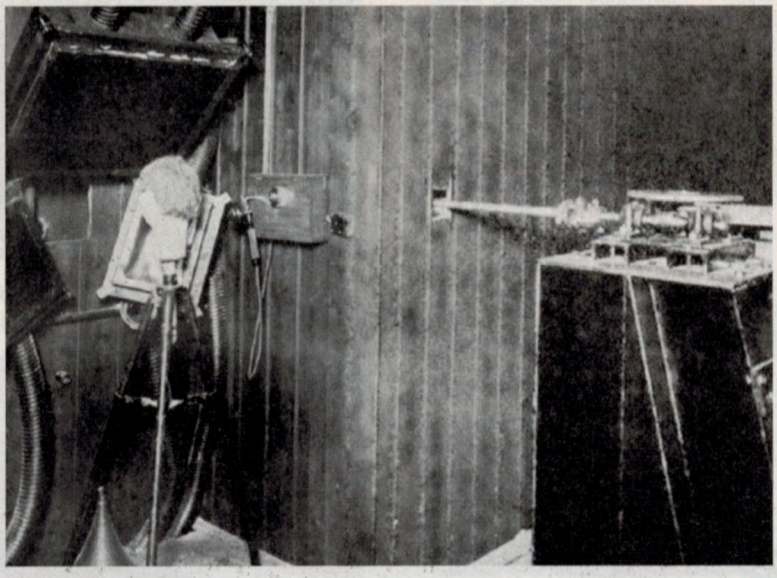


Fig. 10. This rarely seen enhanced view shows – for the first time – the same scanning equipment being used for Phonovision, on the right, and Baird's experiments in near-infra-red light which he called "Noctovision," shown on the left. Often misunderstood and overstated, Noctovision merely exploited the extended red-end response of his photo-sensor.

On the left of the picture, Figs 10, **11**, 12, a ventriloquist's dummy head faces an aperture under blacked-out lights. In the aperture, parts of two lenses are visible, Figs 10, 12. From the computer model, for a 64cm (25in) radius Nipkow disc, the apertures would be just over 13cm (5in) apart, which is what we see on the picture.

When the disc was spinning, the lenses moved from bottom to top. This, and the drive shaft coming out to the Phonovision equipment just 64cm (25in) away, is consistent with a single Nipkow disc centred on the drive shaft.

The overall Nipkow disc would be around 1.5m (5 feet) in diameter. Although we already knew that Baird built large Nipkow discs, this is the first evidence of their use in his pioneering work[15].

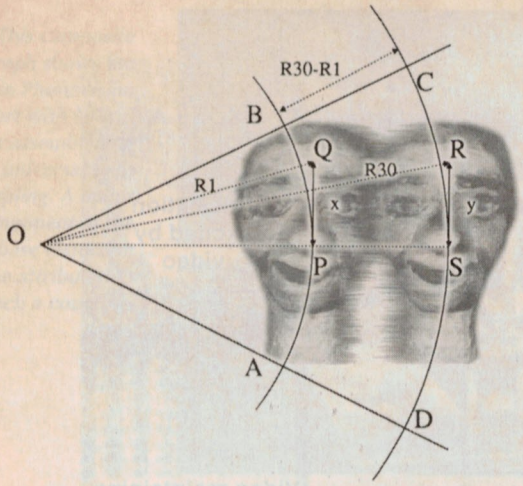


Fig. 13. By measuring the proportional height of a fixed-size object – the centre-line of 'Stookie Bill' – across all lines, we can calculate the image aspect ratio from the unique geometry of arc-scanning.

Arc scanning and aspect ratio

Part way through the earliest Phonovision disc of 'Stookie Bill' – Baird's ventriloquist's dummy head – a hand rocks the head from side to side across all lines in the picture. This good fortune allowed me to use the fixed height of the head to determine whether the camera system was a Nipkow disc or a mirror drum.

A mirror drum generates an image with straight lines whereas a Nipkow disc scans each line in an arc. For the Nipkow disc, an object of constant height moving across the field of view takes proportionately more of the line length the closer it is to the centre of rotation, **Fig. 13.**

Using the centre line of 'Stookie Bill', I measured the proportion of line length across all possible positions and then plotted on a graph. The geometry of arc-scanning allows the aspect ratio of the image to be calculated.[16]

Aspect ratio from arc-scanning. In Fig. 13, ABCD represents the scanned area on the Nipkow disc with angle AOB being $2\pi/30$ – assuming a single spiral per revolution. AB and CD are the paths followed by lines 1 and 30 respectively. For small angles, the object Heights at these extremes are:

$$x/R_1=\sin f$$
$$y/R_{30}=\sin g$$

where f is angle POQ, or $F_1\times 2\pi/30$, g is angle SOR, or $F_{30}\times 2\pi/30$) and $F_1$and F_{30} are the fractions of line length for the respective lines derived from the regression analysis, **Fig. 14**.

For constant object height across the frame, $x=y$, and you can combine the equations to derive an expression for the width, W, of the image:

$$W=R_{30}-R_1=R_1\times(a-1)=-R_{30}\times(1/a-1)$$

where $a=\sin f/\sin g$. Now, the raster height can be expressed b y the arc-length, H,

$$H_1=R_1\times 2\pi/30$$
$$H_{30}=R_{30}\times 2\pi/30$$

Aspect ratio AR is defined as the ratio of height to width of the scanned area, or the average of the instantaneous aspect ratio values on lines 1 and 30.

$$AR=-\pi\times((1+a)/(1-a))/30$$

Using $F_1=0.36037$ and $F_{30}=0.32644$ from Fig. 14 gives $AR=2.12{:}1$

Taking into account the action of rocking the head, the calculated aspect ratio is 2.12 in mid-frame, within 10% of the actual 2.33 ratio, i.e. 7 vertical to 3 horizontal.

Early standard.

There is one departure from the subsequent Baird standard for 30-line television: the first line in the frame was innermost on the disc on the Phonovision discs whereas the standard called for the first line to be the outermost. With Miss Pounsford's hair parting determining scanning direction, Baird's camera used for Phonovision scanned the frame of the scene from left to right rather than the Baird standard of from right to left.

The 'standard' though is for the broadcast period that started in 1929. Baird's television standards had been migrating over the years: his first demonstration in January 1926 had been on 32 lines[17]. With the Phonovision discs we have evidence of early use of the 30-line system with only minor differences from the subsequent broadcast standard.

The Phonovisor

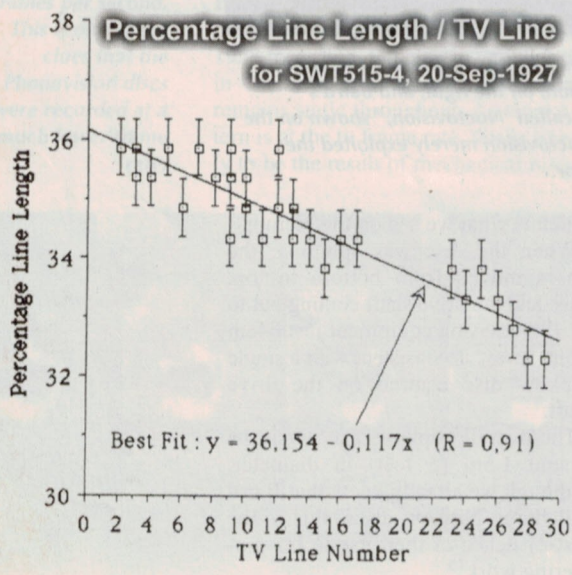
Intended as a mass-market replay device, the Phonovisor was stunningly simple in concept. By mounting the disc turntable of a conventional gramophone onto a Nipkow disc, synchronised playback of pictures through the Nipkow disc would be assured without recourse to electronics or complex mechanics, **Fig. 15**.

The practicalities however make it a challenge, despite the problems in making Phonovision discs.

There is a trade-off between replay rate, number of frames per revolution and displayed picture size. A Phonovisor used to view Phonovision needed a playback speed of 250rev/min to give a Baird television standard picture.

Not only is needle replay not practical at this speed, but the recording is less than a minute long. The viewable picture height on a Baird Nipkow disc is the arc-length between adjacent holes.

Fig. 14. This is a plot for all positions of 'Stookie Bill' head as the operator rocks it back and forth. Regression analysis gives us the smoothed values from which we can calculate the aspect ratio.



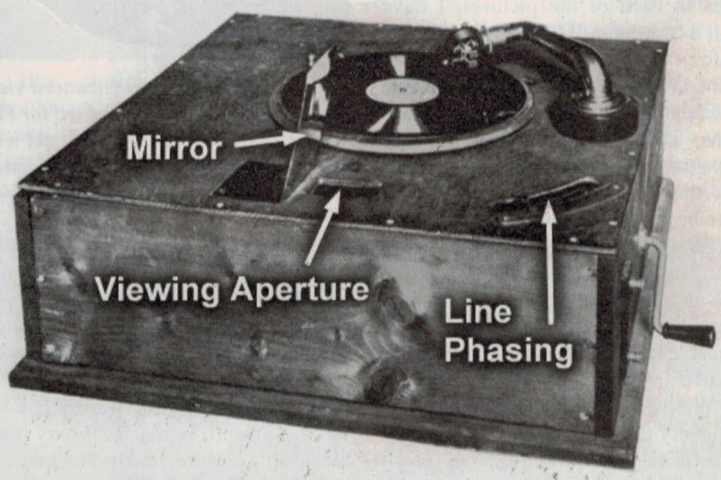


Fig. 15. Mock-up of Baird's Phonovisor showing what he intended to manufacture. Note that the pick-up is mounted backwards. The lever on the right may be either for lining up the image on replay or more simply for adjusting speed.

On a Phonovisor with a 50cm disc, like Fig. 15, the image would be about 17mm by 7mm. It would be proportionately smaller the more frames per revolution.

In summary

Starting from simply the pattern and content of a vision signal cut onto a handful of audio test discs, I have been able to reveal an astonishing amount of detailed new information from these historic pioneering days of television.

The main achievement has been the restoration of what I believe are the world's earliest recordings of television. Television pictures captured in Baird's laboratory in the twenties must be rated among the most important of television's short history.

While the restoration work reveals the latent images, analysis of the content and the corrections applied reveals a wealth of hard facts about Baird's experiments. We now know what type of camera Baird was using, how well it was built, how fast it accelerated to speed, what departures there were to his television standard – even the type of lighting in the studio.

Most importantly, we can now truly appreciate the difficulties he encountered in trying to bring this invention to practicality.

Baird himself summed it up. "...I had a gramophone record made of... (the vision signal) and I found that... I could reproduce the original scene. A number of these records were made... but the quality was so poor that there seemed no hope of competing with the cinematograph."[18]

Finally, I would like to mention that I am indebted to Ray Herbert, ex-employee of Baird and now the Baird Company historian, for his support over the years. ■

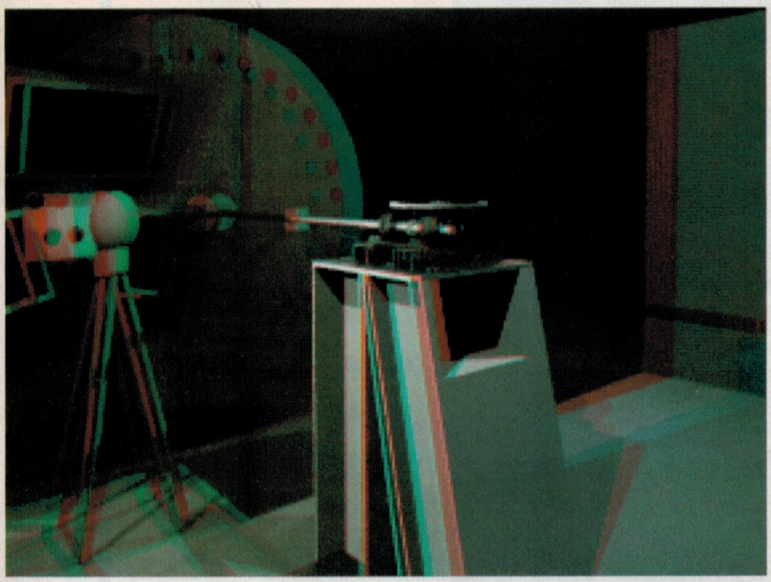


Fig. 11. A stereo anaglyph, requiring red-blue spectacles, of the computer reconstruction of Baird's laboratory, cf Fig. 10.

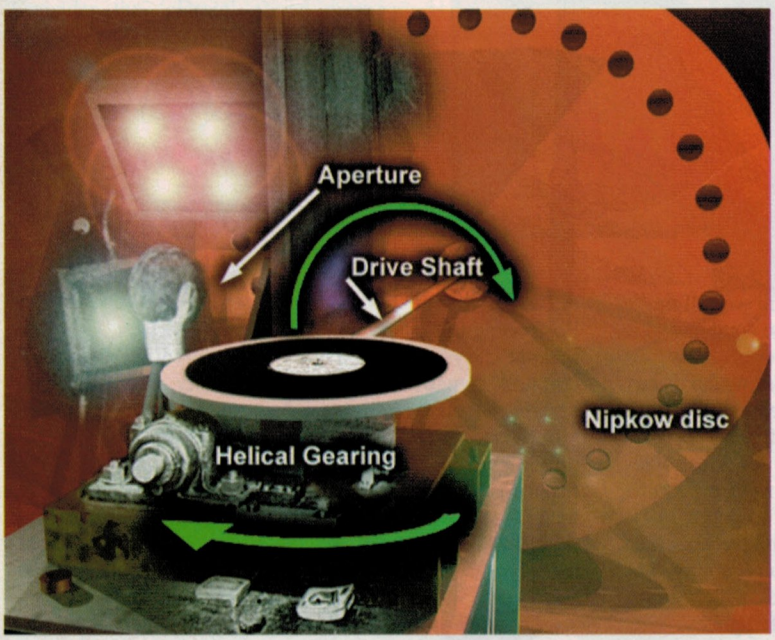


Fig. 12. Knowing the direction of rotation of the turntable from the discs, and following this action through the helical gears, Fig. 7, you can see that the drive-shaft rotated clockwise as it entered the wall. Behind the wall is the most likely arrangement of a large diameter Nipkow scanning disc.

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Courtesy of Ron Roscoe